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SETA-SPIGOT HOMOLOGY AND SILK PRODUCTION IN FIRST INSTAR *ANTRODIAETUS UNICOLOR* SPIDERLINGS (ARANEAE: ANTRODIAETIDAE)

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ABSTRACT: A scanning electron microscope study of the silk spigots of the first free postembryonic instar of *Antrodiaetus unicolor* shows that their spigots and setae are more similar in early instar spiderlings than in the adult spiders. This ontogenetic evidence supports the hypothesis that the silk spigots of spiders evolved from setae. These observations also suggest that spigots with a deep articulation between the base and shaft are more primitive than the non-articulated spigots.

"Among the arachnids, spiders alone produce silk from opisthosomal glands that open through modified setae called spigots, which in turn are located on reduced abdominal appendages, the spinnerets" (Shear et al. 1989). Much is known about the uses, chemistry, and physics of spider silk, but little is known about its evolutionary origin. Several hypotheses have been proposed to explain the evolution of silk production in spiders. McCook (1889) and Savory (1928) (as summarized by Shear 1986) suggest that the primitive arachnids trailed excretory material from coxal glands, serving as a trail back to a safe retreat. However, Shultz (1987) most recently has postulated that silk evolved primarily for reproductive needs, where it was used to construct egg sacs and spermatophores. Rovner (1987) also suggested that silk first served a respiratory function, allowing spiders in flooded areas to construct a silken retreat that exchanged oxygen with the surrounding water. These hypotheses along with others (Decae 1984; Foelix 1982) are derived primarily from knowledge of extant silk use. An alternative approach focuses on the morphology of the spinning apparatus of primitive spiders (Palmer et al. 1982; Palmer 1985). Palmer (1990) proposed two simultaneously plausible hypotheses regarding the evolutionary origin of the silk producing apparatus: 1) the silk glands were derived from dermal glands and 2) silk spigots were derived from sensory setae. Scanning and transmission electron microscope observations of adult female *Antrodiaetus unicolor* show that there are both external and internal similarities between setae and spigots (pers. obs.). If spigots have evolved from setae the two structures should be more similar in early instar spiderlings than in adult spiders. This study examines the surface structure of silk spigots and sensory setae of the 1st postembryonic instar of *Antrodiaetus unicolor* (Hentz). *Antrodiaetus unicolor* is well suited for this investigation because it has the simplest and probably most primitive known complement of silk glands (Palmer et al. 1982; Shultz 1987).

METHODS

The first free postembryonic stage (Coyle 1971) spiderlings of *A. unicolor* used in this study were collected in September of 1992 from an egg sac found near Cullowhee, North Carolina. The spiderlings were fixed in 70% ethanol, run through an ethanol dehydration series, cleaned in an ultrasonic cleaner for 2–5 seconds, critical-point-dried, and sputter coated. Twenty four spiderlings were viewed and photographed using an ETEC Autoscan scanning electron microscope. All measurements given in this paper were taken from one representative specimen.

RESULTS

The abdomen appears to be composed of 12 segments (Figs. 1, 3) with the spinnerets located mid-ventrally. Three pairs of spinnerets are present: anterior lateral spinnerets (ALS), posterior lateral spinnerets (PLS), and the posterior median spinnerets (PMS) (Figs. 1, 2). ALS, PLS, and PMS lack setae but each PLS has one silk spigot (Fig. 2), a feature overlooked by Coyle (1971). The spigot shaft is sometimes curved or slightly tapered, is 4 μm in diameter and 15 μm in length and is distinctly articulated in a swollen base (Fig. 4). Its base is 13 μm in diameter and

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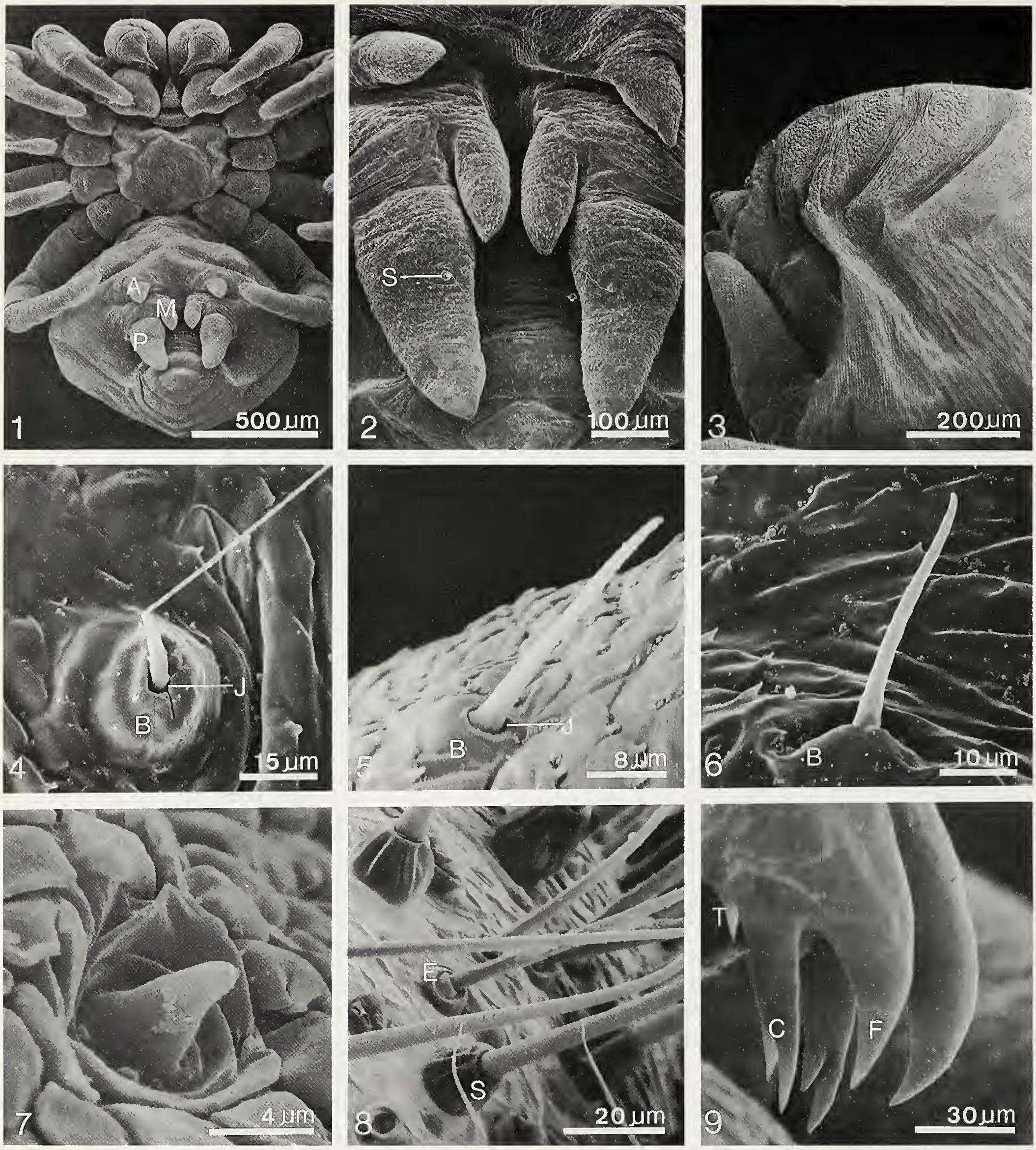

Figures 1–9.—*Antrodiaetus bicolor*. 1. first instar spiderling, ventral view [note ALS (A), PMS (M), and PLS (P)]; 2. ventral view of spiderling abdomen, with ALS, PLS and PMS shown [note silk spigot (S) with silk, positioned mid-ventrally on the PLS]; 3. side view of the spiderling abdomen showing segmentation and mid-ventral position of the spinnerets; 4. silk spigot located mid-ventrally on the PLS [note spigot shaft, spigot base (B), spigot and shaft-base junction (J)]; 5. type I setae, metatarsus of spiderling walking leg, showing shaft, area of shaft-base junction (J), and large rounded base (B); 6. type II setae, coxae of 4th walking leg of spiderling [note shaft and small base (B)]; 7. type III setae, on palpal endite of spiderling (note cone shaped structure seated in a depression); 8. adult *A. unicolor* silk spigots (S) and sensory setae (E) (Micrograph courtesy of F. Coyle); 9. spiderling cheliceral main fang (F), branched claw-like structure (C) and small triangular projection (T).

appears to be centered in a slightly depressed area. These spigots are located 155 μm from the tip of the PLS (Fig. 2) and have a smooth surface. Silk or a silk-like substance can be seen issuing from these spigots (Figs. 2, 4). The only other structures found on the spinnerets are knob-like structures located immediately adjacent to the silk spigot (not shown).

Table 1.—Comparison of the three setal types found on *Antrodiaetus unicolor* spiderlings.

Type	Base	Shaft	Articulation
I	bulbous; 10 μm dia	long/tapered; 30 μm length	evident
II	conical; 16 μm dia	long/tapered; 30 μm length	weakly developed
III	depressed; 3 μm dia	cone shaped; 6 μm length	not evident

Each walking leg has nine setae and each pedipalp has eight: 1 located ventrally on the coxa, 1 ventrally on the tibia, 1 ventrally on the metatarsus, and 3 dorsally and 3 ventrally positioned on the tarsus. Other setae occur on the chelicerae and palpal endites of the spiderling. Based on seta shaft and base architecture, three setal types were identified (Table 1). Type I setae (Fig. 5) are found on the tarsal segments of the walking legs and pedipalps, dorsal side of the chelicerae, and the palpal endites. These setae have a rounded base 10 μm in diameter and a long tapered shaft, 30 μm in length, with a distinct shaft base articulation. Type II setae (Fig. 6) are found primarily on the coxae and the ventral side of the tibiae and have a conical base 16 μm in diameter, a shaft 30 μm in length and a weakly developed shaft-base articulation. Type III setae (Fig. 7) have a cone-shaped shaft 6 μm in length and 4 μm in diameter seated in a depression. Little or no shaft-base articulation is evident. This type is found only singly on the palpal endites and may not be homologous to "true" setae.

In adult *A. unicolor*, the morphological differences between silk spigots and sensory setae are much greater (Fig. 8). The spigot (Fig. 8, structure S) projects from a sac-like base, similar to the spigots of *Euagrus* described by Palmer (1985), and is long and slender with faint distal scale-like topography. In contrast the shaft of the mechanoreceptor seta (Fig. 8, structure E) projects from a small, ball-joint-like base and is covered with small spines.

The cheliceral fang has a peculiar form at this stage of development (Fig. 9); it appears to be composed of three parts: 1) a main fang, 2) a long claw-like, bifurcate projection, near the distal end of the fang, and 3) a smaller triangular projection located distal to the bifurcate structure.

DISCUSSION

The most interesting finding of this study is the presence of functional spigots on the first instar spiderling of *Antrodiaetus unicolor*. Galiano (1972) also reported spigots in first instar spiderlings of the diplurid *Ischnothele seimensi*. These discoveries will require a revision of Vachon's (1957) often cited criteria of larval (as opposed to nymphal) spiderlings, which he characterized as lacking spigots, and Downes' (1987) criteria of postembryonic spiderlings, which he describes as lacking functional spinnerets.

The presence of a functional silk-producing apparatus at such an early stage of development raises intriguing questions. How do the spiderlings use this silk? What is the chemical composition and physical properties of the silk at this developmental stage? What is the location and structure of the silk glands and associated structures? Is the silk gland located in the abdomen or associated more closely with the spigot base?

The form of the shaft of Types I and II setae in *A. unicolor* spiderlings is similar to that of the silk spigots and all of these shafts lack surface topography. The base of the silk spigot is strongly articulated like that of the Type I setae. Although a highly differentiated base exists on the spigot it is not as rounded as that of the Type I setae. This spigot base appears to be an intermediate between that of Types I and II setae and much more like a seta base than is the case in the adult instar.

In summary, the morphological similarities between the silk spigots and setae of first instar *Antrodiaetus unicolor* spiderlings support the hypothesis that silk spigots have evolved from setae and may suggest that silk initially functioned as a sensory mechanism. The non-articulated shaft-base junction of the spigots of the archaic Liphistiidae, which have a long, gradually tapering, unsculptured distal shaft that merges smoothly into the broad conical base (Shear et al. 1989), have been considered a primitive feature. However, the strong articulation at the base of the spiderling spigot suggests that the liphistiid spigot may be derived. Additionally, the claw-tooth-like structures observed on the rudimentary cheliceral fang support the hypothesis that the fang is homologous to the claw of the pedipalp.

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